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Advanced methods for determining emergency planning zones for innovative small reactor designs

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1. METHODS ASSUMPTIONS

- Dose consequence models are essential for nuclear safety analysis, especially in assessing radiological impacts from nuclear accidents.
- New reactor designs are often located closer to populated areas and feature smaller Emergency Planning Zones (EPZs).
- Accurate consequence analysis is critical for defining effective and practical EPZs.
- Traditional approaches using single weather scenarios or simplified transport models are insufficient.
- Propose method uses statistical analysis of multiple meteorological scenarios via Monte Carlo simulations.
- Spatial dose distributions were compared with EPZ dose limits and distances from reactor sites.
- The study demonstrates the potential to adapt emergency planning to advanced reactor technologies, enhancing safety and land-use efficiency.

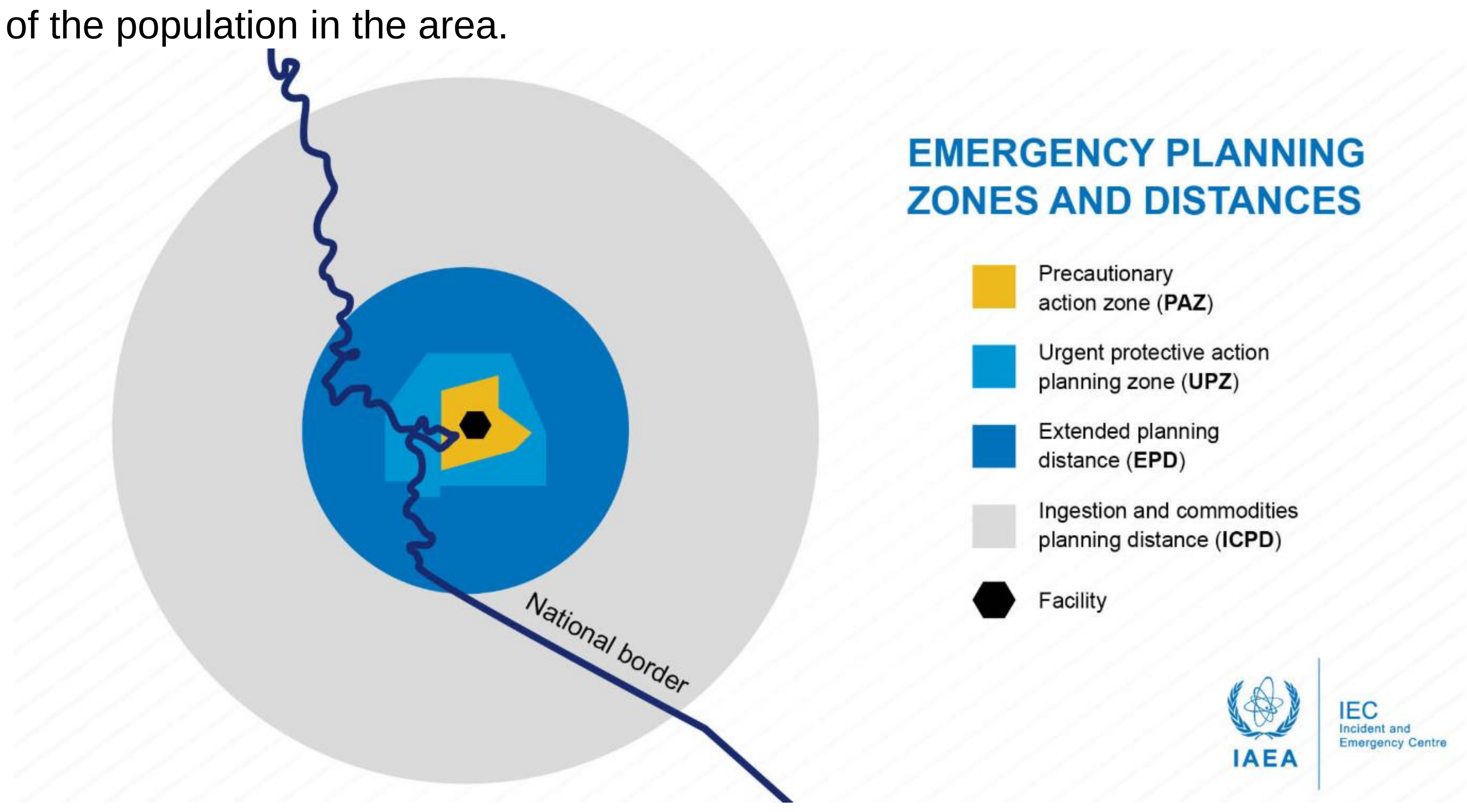
2. EMERGENCY PLANNING ZONE

According to PAA guidelines for Category II facilities, which include research reactors, fuel processing plants, isotopic enrichment and nuclear fuel production facilities, and radioactive waste repositories, specific zones with defined limits are assessed:

The *Urgent Protective Action Planning Zone* (UPZ): An external zone designated for immediate intervention planning. This zone encompasses effective doses from both external and internal exposure, excluding the ingestion of radioactive substances (≥ 100 mSv) and an equivalent dose to the thyroid from the ingestion of radioactive iodine isotopes (≥ 50 mSv).

The *Extended Planning Distance* (EPD): A zone for expanded planning, which involves an effective dose greater than or equal to 100 mSv from both external and internal exposure, including the ingestion of radioactive substances.

The *Ingestion and Commodities Planning Distance* (UCPD): A zone for consumption planning and commodity control, which includes a dose of 10 mSv or more from the ingestion of food and drinking water, considering the local dietary habits of the population in the area.



3. JRODOS (Real-time On-line DecisiOn Support)

JRODOS is designed to assist decision-makers in mitigating the consequences of radioactive releases after a nuclear incident, applicable in national or regional emergency control centers.

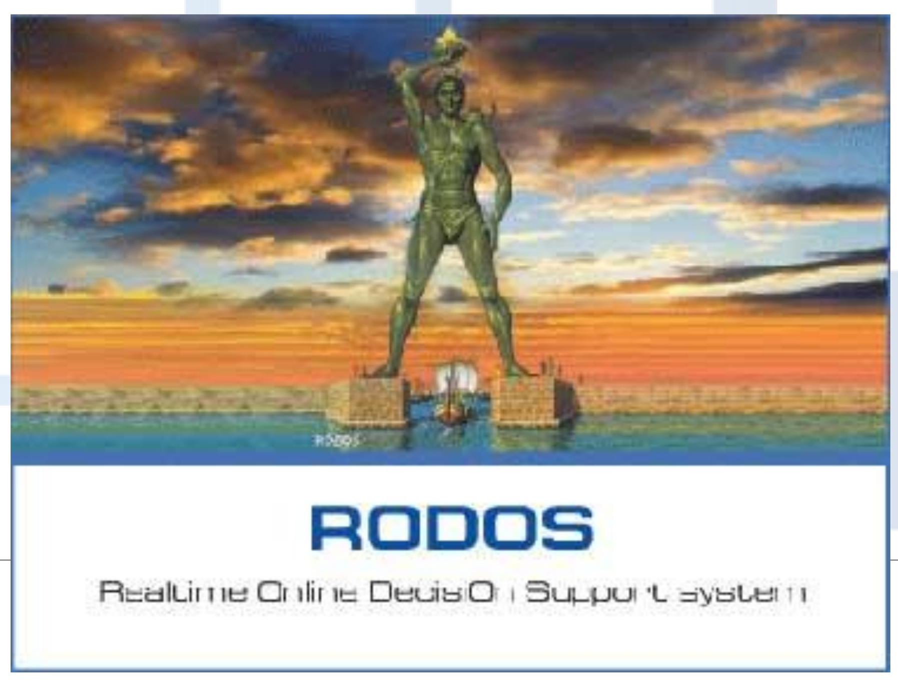
Diagnostic Mode: Uses real-time local meteorological data for current situation analysis.

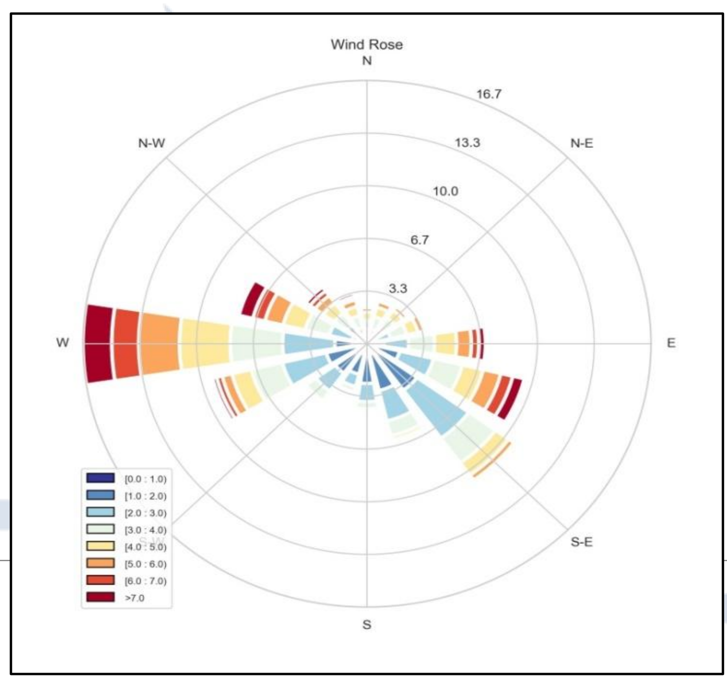
Prognostic Mode: Uses atmospheric dispersion models to predict the spread of radioactive substances on both local and continental scales.

Local-Scale Models: RMPP: Meteorological pre-processor, RIMPUFF: Puff diffusion model for short-range dispersion. Dipcot: Lagrangian model for local dispersion.

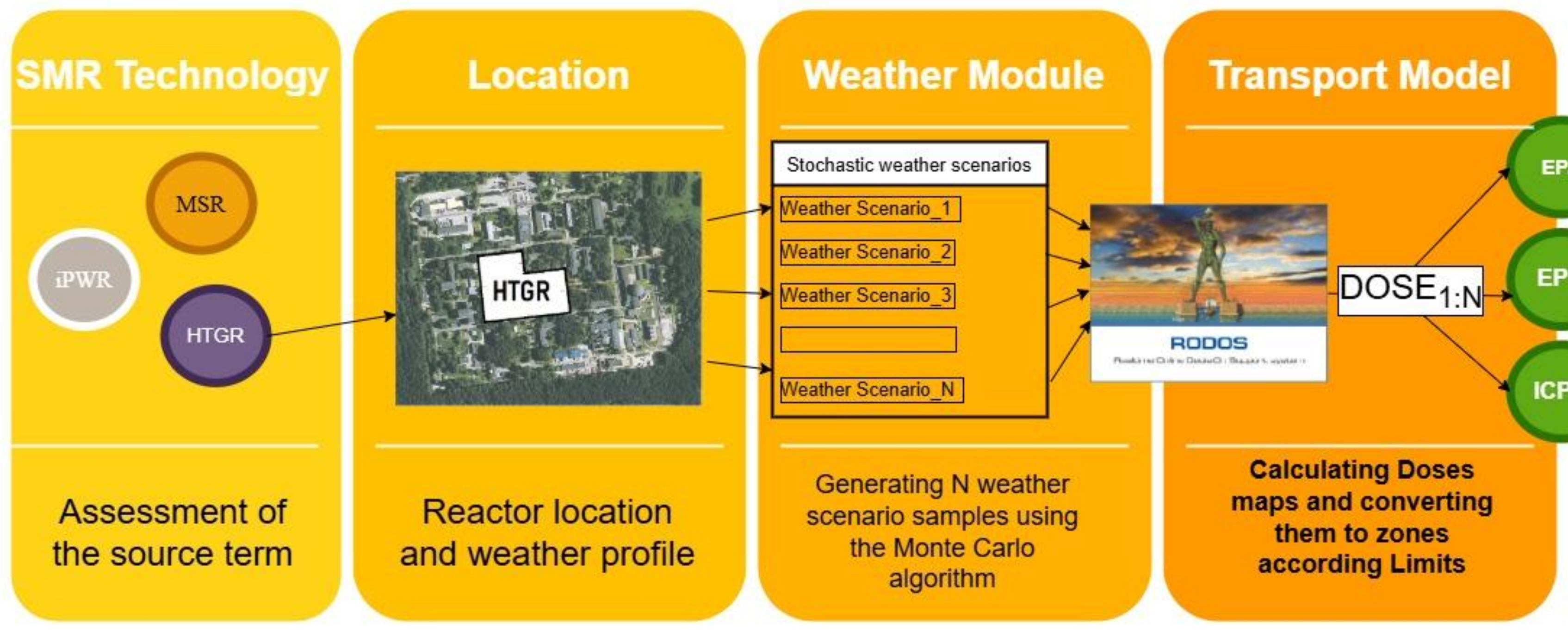
Long-Range Models: MATCH: Eulerian model for long-range atmospheric dispersion. **LASAT**: Lagrangian model for long-range scenarios, with some limitations.

Radionuclide Transfer Modeling: DEPOM: Models deposition from the atmosphere to the ground and food products. FDMT: Calculates radionuclide transfer through the food chain, requiring customization based on regional climate, agriculture, and dietary habits.





4. METHODOLOGY FRAMEWORK



6. Key Considerations for HTGR Reactors: Weather Scenario and Source Term Determination

Importance of Weather Scenarios:

The choice of weather scenarios is critical for calculating zones and areas affected by radioactive releases. Conservative weather assumptions, such as stability class A and low wind speeds, can greatly influence dose values and distances.

Regulatory Recommendations:

Regulators should define specific weather scenarios for different locations to eliminate ambiguities and disputes between investors and regulators regarding worst-case scenarios.

Source Term Determination:

Accurate determination of the source term is essential, as it significantly affects the calculated zones and areas. The source term derived from MELCOR simulations is much lower than conservative estimates found in existing literature, which often overestimates release fractions.

Comparative Analysis:

The study from Idaho National Laboratory provides insights into a different HTGR accident scenario (D-LOFC with scram without air ingress), demonstrating the need for precise calculations of release fractions relative to iodine-131.

Need for Improved Calculations:

It is crucial to verify that the proposed source term aligns with worst-case accident predictions using updated computational codes.

Conducting simulations with codes comparable to MELCOR can help accurately assess source terms.

Recommendations for HTGR and SMR:

For low-power HTGR reactors, precise calculations of radionuclide transport following severe accidents should be performed using Computational Fluid Dynamics (CFD) codes for better hazard assessment.

Establishment of Guidelines:

It is recommended to create a definitive list of required weather conditions for which EPZs and distances should be calculated to prevent overly favorable assumptions. Areas of interest should be grouped based on similar weather conditions, akin to EPA recommendations for dispersion modeling, to ensure rigorous analysis of severe accidents in nuclear facilities.

7. Acknowledgments

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